Regional impact of re-vegetation on water resources
A case study in the Loess Plateau

Rui Li[1] – Qinke Yang – Zhongmin Wen – Xiaoping Zhang – Xingmin Mu – Peng Gao – Zhihong Liu – Wenzhao Liu – Chunyan Liao – Tim R. McVicar – Tom G. – Lu Zhang – Van Niel – LingTao Li

[1]Institute of Soil and Water Conservation, CAS/MWR; No 26,Xinong Road, Yangling, Shaanxi province, 712100, China, Tel: 86-29-87012061; FAX: 86-20-87012210; E-mail: lirui@ms.iswc.ac.cn

1. Abstract

Re-vegetation is considered one of the most efficient measures for controlling severe erosion on the Loess Plateau. Many research results show that re-vegetation can make impacts on water resources, such as hydrological circle attributes, runoff and soil water. This research was performed in the Coarse Sandy Hilly Region of the Loess Plateau. The objective was to develop a software tool to evaluate and predict the impact of re-vegetation on water resources. The outputs include regional spatial databases for climate, river flow, land use, vegetation and DEMs, and vegetation suitability assessment models. Based on these models a series of maps of the suitability and longevity of the proposed re-vegetation schemes can be produced by the developed tool, taking into account rainfall, potential ET, water requirements of different vegetation types, landscape position and changes to the soil moisture. A decision support tool called ReVegIH (Re-Vegetation Impacts on Hydrology) was developed from this project. ReVegIH provides a means for users to: (1) determine where priority (and target) re-vegetation activities should be undertaken; (2) ascertain what species are suitable for a specific location; and (3) simulate the related hydrological impact, and should therefore greatly assist in environmental planning and management within the Yellow River Basin.

2. Introduction

Re-vegetation is widespread in China; the Chinese Central Government has enthusiastically implemented the “Clean River: Green Hills” policy. This policy will run from 2000 until 2050, hence impacts in the initial stages of the policy have a large potential impact on the policy implementation. The current solution to severe erosion on the Loess Plateau is to re-vegetate large tracts of land, including some agricultural land, using perennial plants (grasses, shrubs and trees) where appropriate. The aim of the re-vegetation programme is to reduce soil erosion and thus improve water quality of the Yellow River.

Initially (to 2010), the Chinese Central Government will spend 100 billion Yuan to control land degradation. The Loess Plateau is a focus area as it has the highest erosion rates of the entire country. In areas designated for re-vegetation by trees, farmers will receive 750 Yuan per hectare for the first 5 to 8 years. This money will be used to establish nurseries to grow suitable seedlings and to assist farmers to purchase the seedlings. By 2010 in the upper and middle reaches of the Yellow River (including the Loess Plateau), 75% of sloping land and 46% of desert areas will be re-planted using tress, shrubs and perennial grasses depending on climate and landscape position. The Chinese Central Government is expected to continue re-vegetation schemes in the mid-term period (2010 to 2030), and they hope to start to see obvious benefits in the final period (2030 to 2050). Hence developing a readily available Web-based GIS tool during the initial re-vegetation planning stages will have a large impact on the entire 667,000 km^2 Loess Plateau.

Large scale tree planting has resulted in a significant reduction in stream and river flows. Also there are some very deferent opinions on it. Someone said, “A patch of trees is a water reservoir”. Someone said, “ One tree is a water pump.” Someone said,” Soil and water conservation practices will aggravate water resources crisis of Yellow river.” Someone said, “Soil and Water conservation is one of the measures to solve water resources problem of Yellow River.” What is the true story? How to judge them? This project wants to do some work for answering this question. The main question addressed in this project focuses on estimating how much water will be lost or gained as re-vegetation schemes increase in area. The approach is to develop and apply a process-based model using spatial data. The outputs will be a database relevant to calculate water use by different vegetation types for the regions studied. A CD based estimator of the reduction in water yield given different levels of re-vegetation is anticipated.

3. Study area

This project is supported by ACIAR and was carried out on the Coarse Sand Hilly Region (CSHR), which is about 1/5th of the Loess Plateau (LP). Specific test areas are the Yan'an demonstration area (YDA), the Yanggou Catchment (YGC) and the Yanhe Basin (YHB). The Loess Plateau lies in the central west of China, in the middle reaches of the Yellow River, see Figure 1. The Loess Plateau consists of unique loess hills, sand-loess hills and loess tableland, with many gullies. Winter wheat and summer corn are the main crops, with several orchard fruits (e.g. apples) recently becoming increasingly important to the agricultural economy, and extensive grazing in the northwestern portion of the plateau. Average annual rainfall ranges from to 650 mm (in the southeast) to 200 mm (in the northwest). Thus the Loess Plateau straddles the semi-humid, semiarid and arid climatic zones. Over 60% of the rainfall occurs in the summer monsoon (July to September) season. As rainfall is low and variable, water is the most important factor limiting agricultural production in the region. In the long history of cultivation, natural and social factors have led to a low proportion of vegetation cover, resulting in severe soil erosion, especially at the onset of the intense summer monsoon rains. The severe soil erosion from the CSHR (see Figure 1) has partly filled the Sanmenxia Dam, a major dam on the Yellow River constructed in the 1950's for flood control.

The Coarse Sandy Hilly Catchments (CSHC) are located in the middle of the Loess Plateau covering 0D11 e 10^6 km^2 (Figure 1). This region is the most severely eroded area of the Loess Plateau, in that the CSHC 0D04 e 10^6 km^2 have soil losses greater than 15 000 tone km^{-2} $year^{-1}$. The northwest of the CSHC is sandy with low precipitation, and numerous small ponds have developed due to high groundwater levels. The gully density in the southeast varies from 2 to 8 km^{-2} indicating severe soil erosion. The average annual precipitation in the CSHC is 456 mm ranging from 580 mm in the southeast to less than 300 mm in the northwest. The average annual temperature ranges from 6 to 14 °C, and the average annual pan evaporation is 1500 to 2000 mm, which is about 3 to 7 times that of the precipitation. Average annual stream flow was averaged from monthly and annual data in 38 nested catchments of the CSHC.

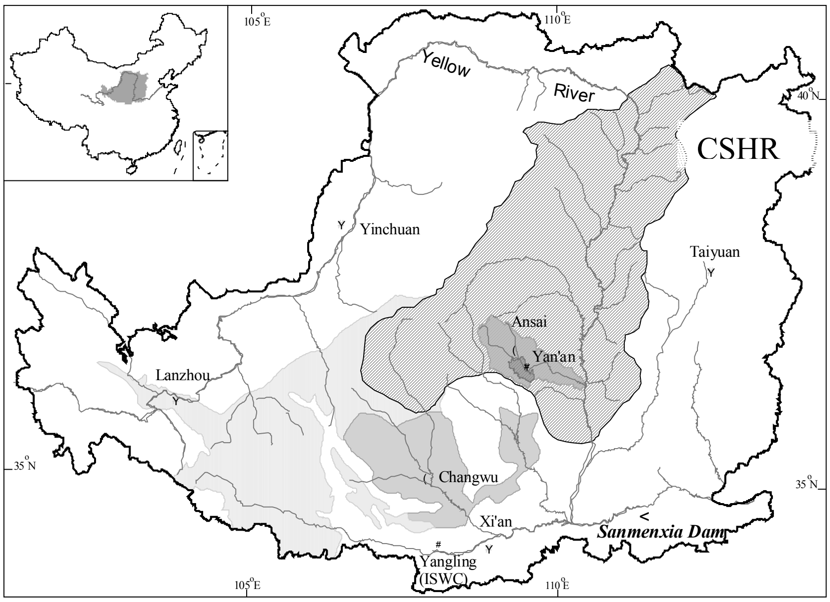

Figure 1 Location of the 707 km^2 Yan'an Demonstration Area (YDA containing Yan'an) contained within the 7,673-km2 Yanhe Basin (YHB also containing Ansai). The YHB lies within the 134,050 km2 Coarse Sand Hilly Region (CSHR shown by the hatching) that contributes over 73% to the bed load of the Yellow River. The remaining light grey area (containing Lanzhou) is the remaining Hilly Region, whereas the mid grey shaded area (containing Changwu) is the 31,000 km2 Tableland Region. The location of Sanmenxia Dam that is filling with sediment is also shown. The 667,000 km2 Loess Plateau is enclosed by the thick dark line of the main map and shaded grey in the insert map of China.

4. Data and methods

The data include five raster datasets (land-use/land cover, digital elevation model (DEM), re-vegetation areas, vegetation suitability and precipitation) and two vector datasets (catchment boundaries and county boundaries). Land-use/Land Cover dataset: the source vector database was mapped in 1986 at a scale of 1:500,000, which was converted to raster data with a cell size of 100 m. These data were later over-sampled to

500 m resolution for display purposes only. Following the hydrology-land-use construct of the land-use classes of forest, sparse forest and shrub-lands have been aggregated to a perennial woody vegetation class (meaning deep-rooted perennial vegetation whose water requirements are different from grasses). The elevations for the CSHC range from 312 to 2760 m above sea level, and slopes can exceed 308 from horizontal in the 100 m resolution model. Re-vegetation area dataset: this spatially defines (at 100 m resolution) where the recommended areas are for re-vegetation.

4.1 Monthly databases of climate and stream flow data from 1980 to 2005, and soils, topography, and land use databases for the YHB

For the entire YHB, monthly rainfall and potential evaporation surfaces will be interpolated from point measures recorded from January 1980 until December 2005, see Figure 4. The data from January 1990 onwards must be purchased. Stream flow data will be acquired from five hydrology stations (see Figure 4) within the YHB for the same period as the meteorological data; again, the data from January 1990 onwards must be purchased. The development of interpolated meteorological surfaces and runoff databases will be added to the GIS data held by ISWC. Soils maps are currently held in digital format within ISWC, the main attributes mapped are type, and some chemical and physical properties. The soil map scale is 1:100 000 for the entire YHB, and for the entire 7,673 km2 YHB, a 40m resolution DEM already exists. By the start date of the project (Jan 2003) land cover attributes will be available for 1980, 1990 and 2000 derived from remotely sensed data for the entire YHB. Currently, 1990 and 2000 are available and the 1980 map is work in progress at ISWC. The 1980 map is being derived from 80 m resolution Landsat MSS data, whereas 1990 was derived from 30 m resolution Landsat TM, and 2000 from 15 m Pan channel on Landsat-7. There are 8 main classes (each with some sub-classes) mapped consistently to Chinese Central Government specifications for the 3 dates. Potential land cover maps for re-vegetation will become available by December 2004. A map of land cover will be developed early in the summer of 2005 (May-June), will be ground truthed and will be available for GIS modelling in the final review / workshop to be held in late 2005. This means landcover will be available from 1980 to 2005 for the final workshop held in late 2005. Using current data will mean the simulations are more appealing to regional agricultural policy makers. This 2005 landcover map will be generated as a direct result of this ACIAR project. The development of GIS data for 25 years is an extensive undertaking, and is based upon much longer-term developments of DEM and soils maps that ISWC have heavily invested in over many years.

4.2 Annual rainfall and runoff data from 1980 to 2005, and topography and land cover databases for the CSHR

The Coarse Sandy Hilly Region (CSHR) of the Loess Plateau covers 134,050 km2, straddling eastern Shaanxi and western Shanxi Provinces, and is comprised of 45 main sub-catchments. For the entire CSHR, annual precipitation will be interpolated from 90 stations, and annual river flow will be purchased for the 23 catchments where 62 stations exist. To avoid errors of winter snowmelt, we plan the annual period to be from 1 April to 31 March the following year. This allows 'snow-melt' to contribute to runoff in the year the precipitation fell. The 100m resolution DEM has been obtained from 1:250,000 data for the CSHR. The 1:100,000 land-use map that can be used to map the current area of trees / no-trees for the 45 catchments of the CSHR.

5. Results

5.1 Assemble regional databases of climate, river flow, land use and topography

The project has successfully completed the development of regional databases to the level required by the project in both countries. These databases include monthly climate and stream flow from 1980 to 2005, soil parameters, land use and topography for the target regions. The terrain data were used to recognize the 5 priority (target) areas for the re-vegetation impacts model. In addition extensive tests for data accuracy have been carried out. The difficulties encountered in assembling a relevant database from existing disparate sources are often underestimated. In completing this task for the regions in China and Australia on time the project team should be congratulated. This exercise has shown that data can be successfully collected and it lays the foundation for future water related work in the regions.

5.2 Map suitability assessments for trees, shrubs and perennial grasses taking into account equilibrium soil moisture

Suitability assessments (species available, growth potential, survival, commercial potential) for trees, shrubs and perennial grasses have been completed successfully. Completion of this task was greatly assisted by expertise from within the local university departments supplying knowledge about botanical, agronomic and forestry aspects of the assessment. Priority areas (target areas) have been identified on the basis of topographic location to assist in species selection and for implementation. Equilibrium soil moisture data were collected from pairs of sites (intact and cultivated) from the Yanhe Basin and rules developed to extrapolate to the coarse sand hilly region (CSHR) in the Loess Plateau. The field sampling used only a single soil core from each site, and this is barely adequate.

5.3 Developing a GIS tool to predict the impact of re-vegetation on annual and seasonal stream flow

The GIS-based software has been developed for the Loess Plateau regions to predict the impacts of various levels of re-vegetation on annual stream/river flows. The work on seasonal stream distributional curves (% small to large flows) has also been completed. Outputs have been tested on data sets available from several locations around the world. A lack of information about the location and time of establishment of sediment dams in the Loess Plateau has restricted testing in that region.

5.4 Developing a Web-based interactive scenario-modeling tool using CRC_CH Toolkit to port the GIS tool

The CD tool developed for the Loess Plateau uses pre-processed data (i.e. is not an input-output product) from #1 above and is user friendly. By pointing the cursor at any location on the map of the Loess Plateau, the screen displays annual rainfall at that location and current flows into streams. A sliding bar resets vegetation cover from zero to 100% and the impact on stream flow is displayed for trees, or shrubs or grasses. It was recognized at the mid-term review that most effort should be put into the completion of the CD version of the tool for the Loess Plateau. The existing tool was developed to address questions at the broad regional scale and can easily cope with more data sets at that scale.

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